Suppression of Timing drift between laser and electron beam driven photo-cathode RF gun

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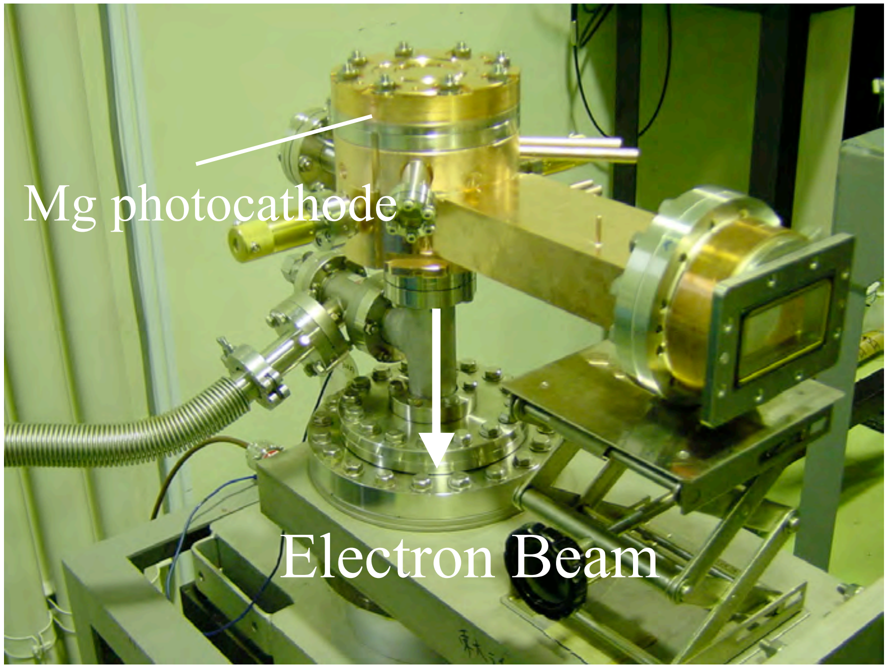
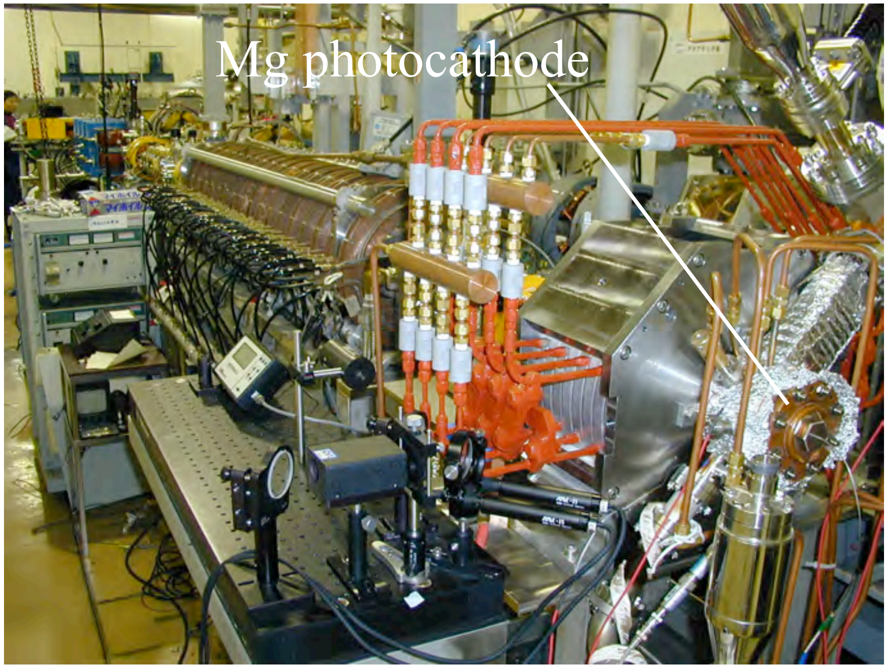
UTNS Linac & Mg Photocathode RF Gun



▽ 18 MeV Linac with the RF gun

△ Mg photocathode
\+
BNL type IV RF gun



Our cathode : Mg cathode

- **Work function of Mg corresponds to 3.66 eV**

↓

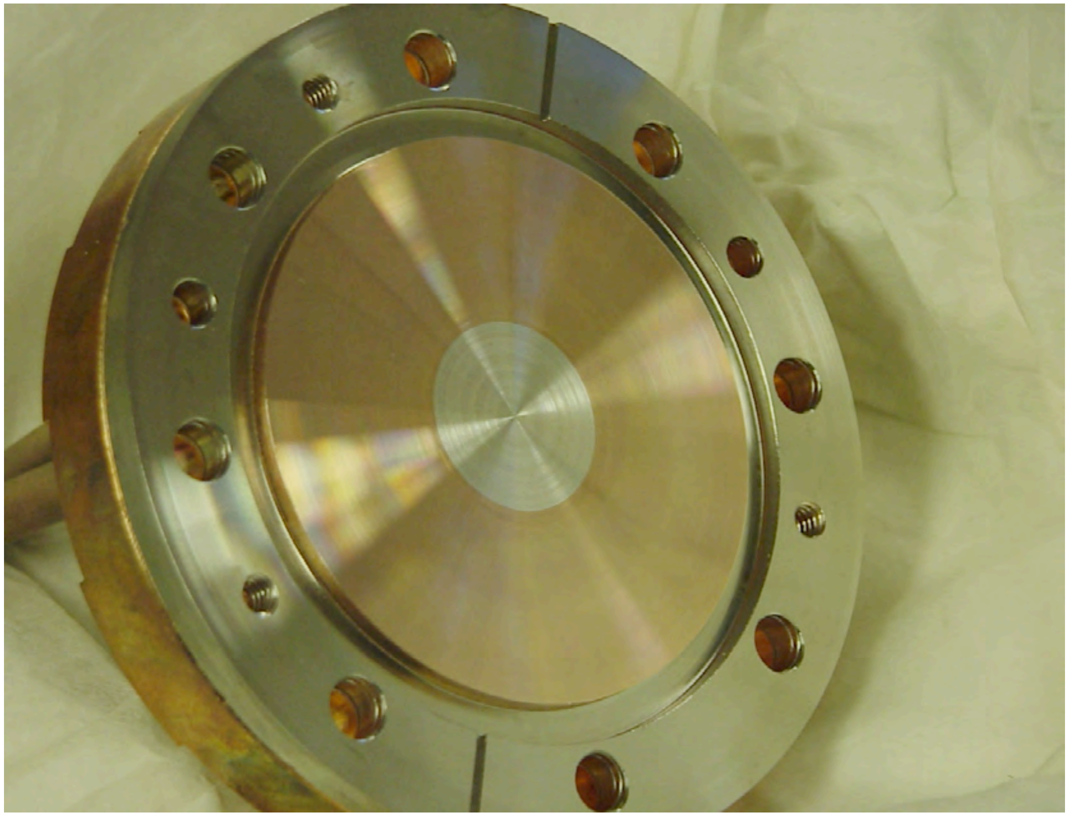
- **Ti:Sa third harmonic （266nm、~4.7eV)**

Quantum efficiency

Aiming QE, ~10^{-3}(BNL)

Q[nC]~QE*λ[nm]/124*E[uJ]

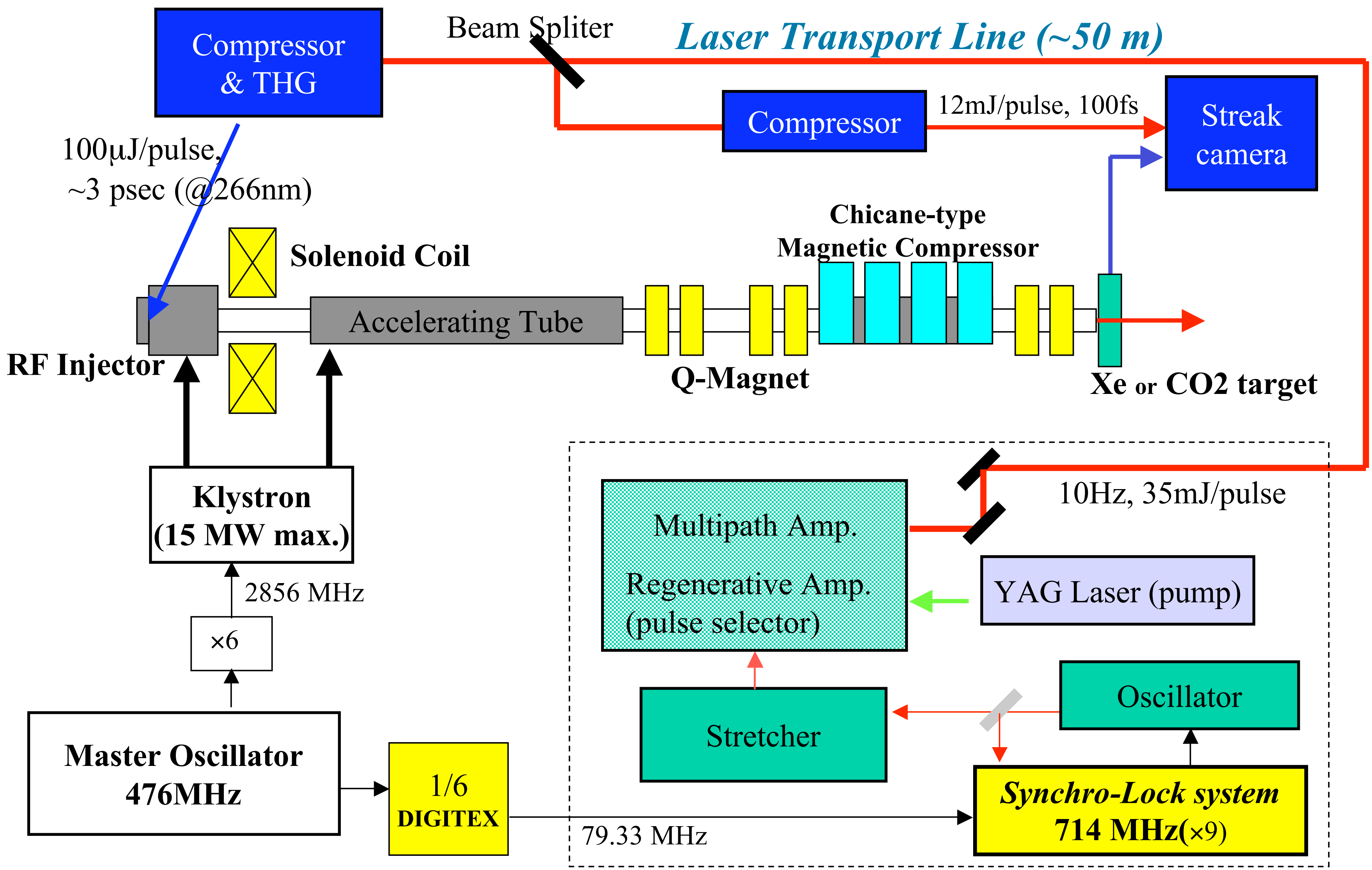
- Long life (>year)



Performance of RF Injector

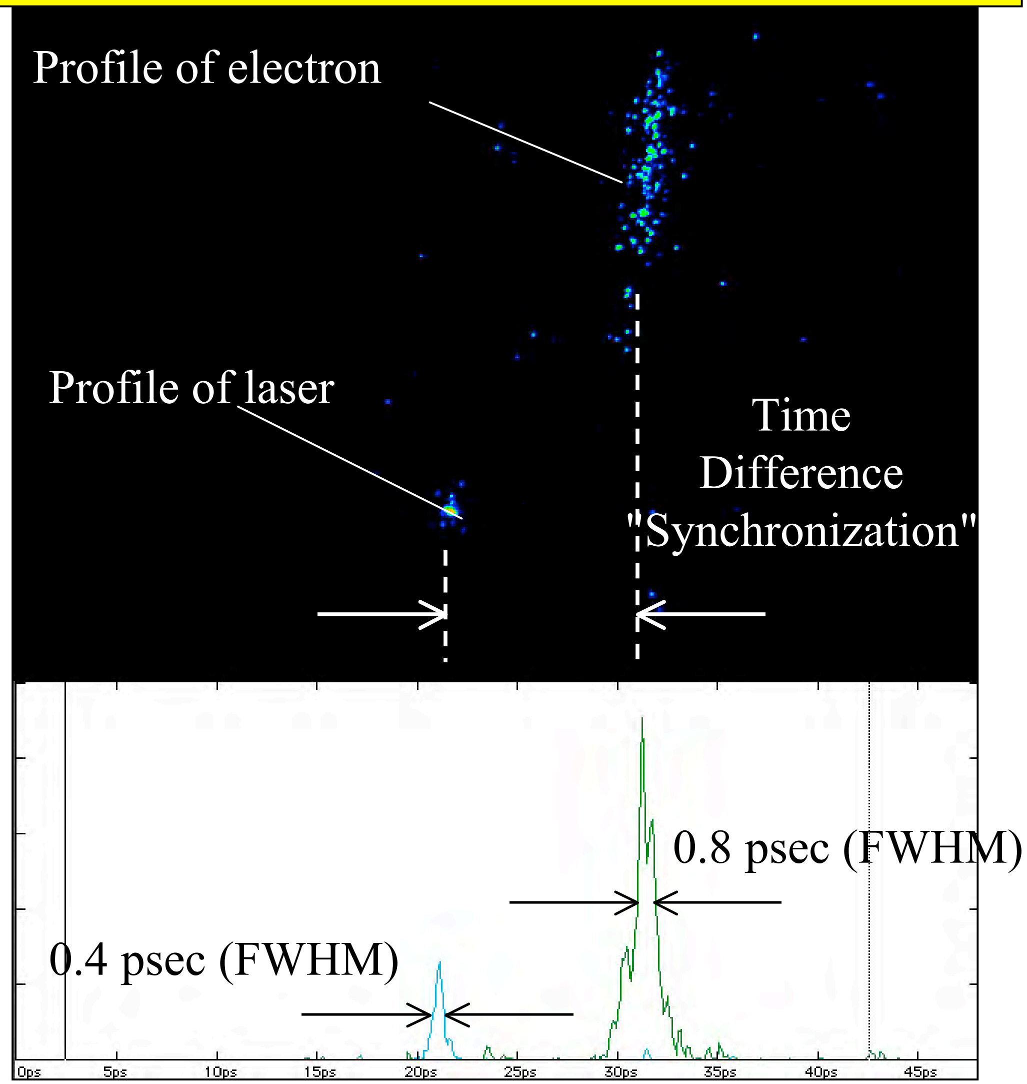
RF Injector			RF	
Cathode		Mg	Power	6.0 MW
Q.E.		1.3×10^{-4}	Pulse Duration	2 μsec
Charge		1nC/bunch	Repetition	10 Hz
		Up to 3nC/bunch	**Laser**	
Dark Current		800 pC/bunch	Driven Laser	Ti:Sapp., THG
Emittance	Horizontal	26 πmm・mrad	Laser Energy	100 μJ/pulse
	Vertical	24 πmm・mrad	Laser spot size	φ3mm
Bunch Duration		0.7 ps (1.5 nC, FWHM)		
Beam Energy		22 MeV		

Experimental setup and Synchronization System



Requirement of stable synchronization

Typical Femtosecond Streak Camera Image of Synchronization



• The S-band linac with Mg photocathode RF injector has been developed for radiation chemistry.

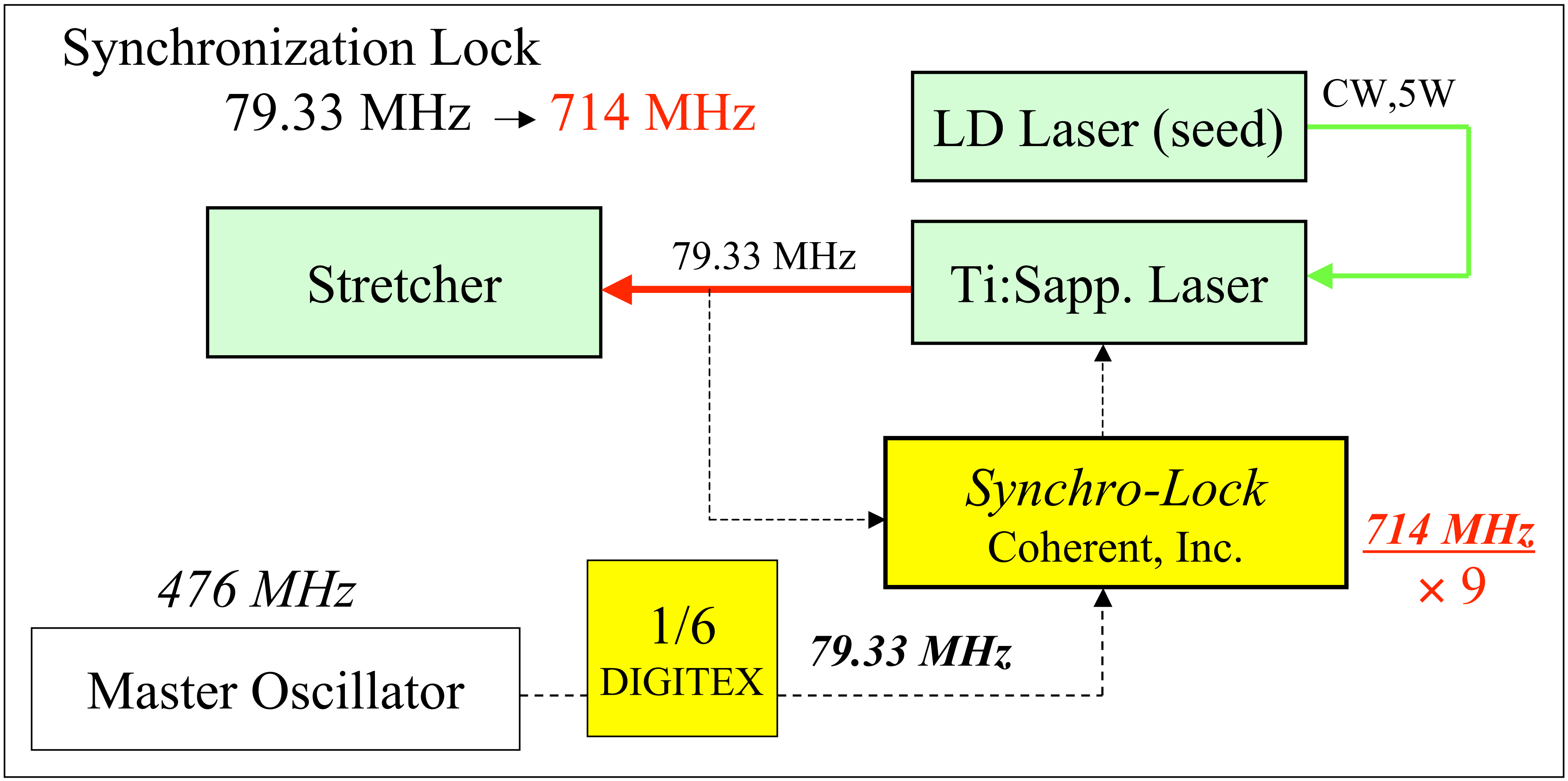
• The radiation chemistry experiment requires a time resolution in a range of sub-picosecond.

• The time resolution is defined by… *pulse duration of pump-beam, and probe-laser, synchronization between the beam and laser, and the beam intensity*.

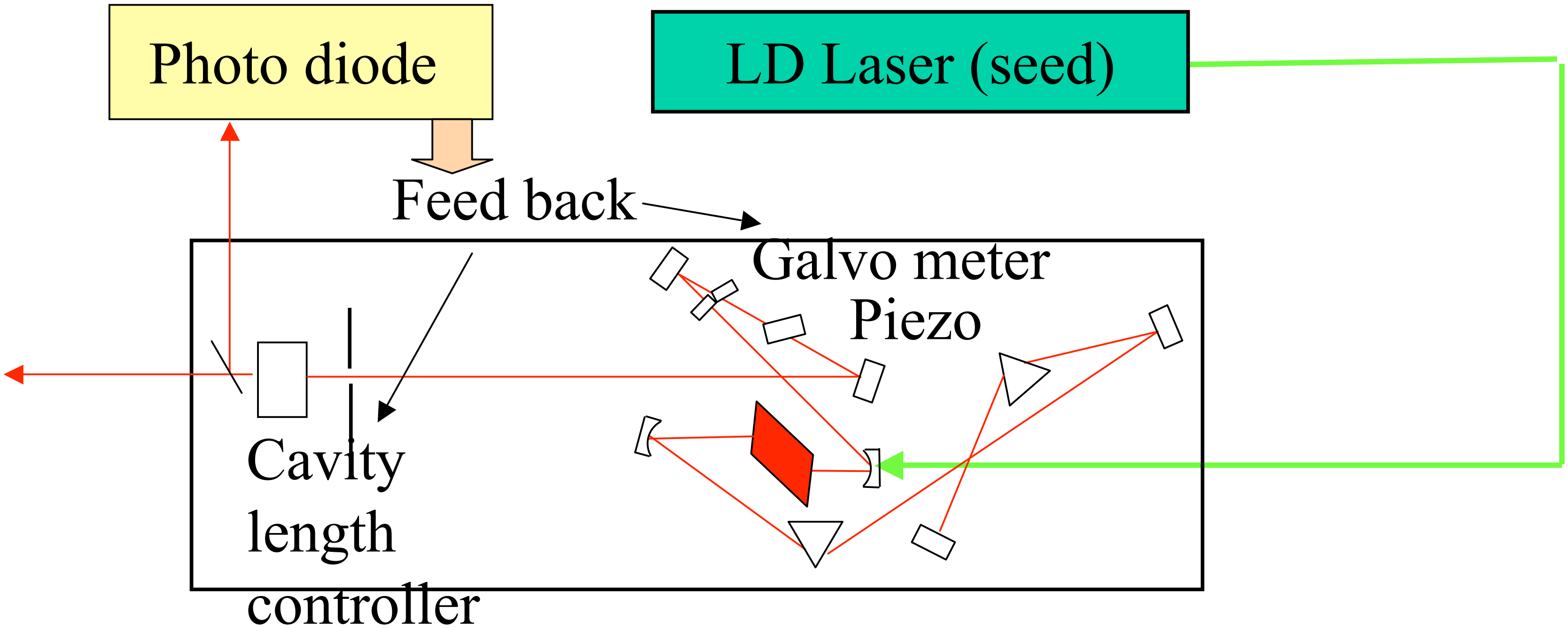
We can control the time difference between laser and electron beam by optical delay line.
The fluctuation of time difference is important.

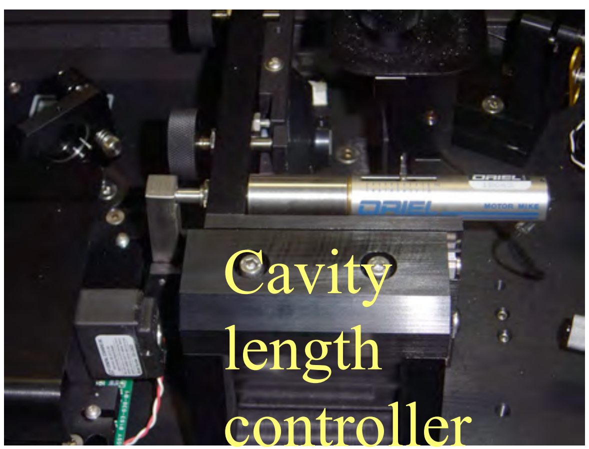
Laser-RF Synchronization System

The oscillator with 476 MHz is used as the master clock. The laser clock is controlled by the 1/6-multiplied master.

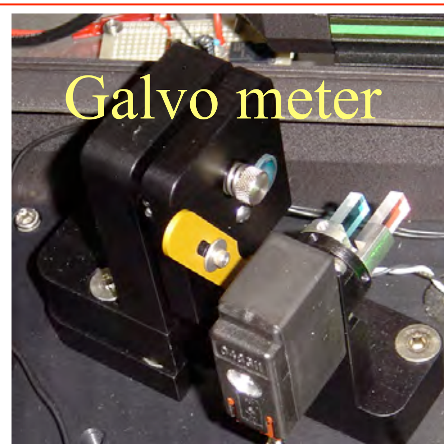


Oscillator feedback system

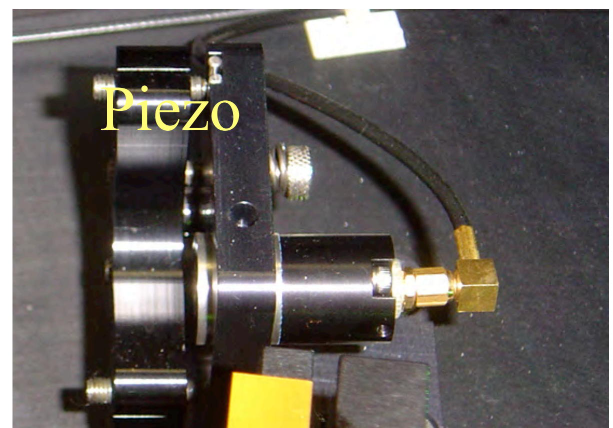




Roughly optimization

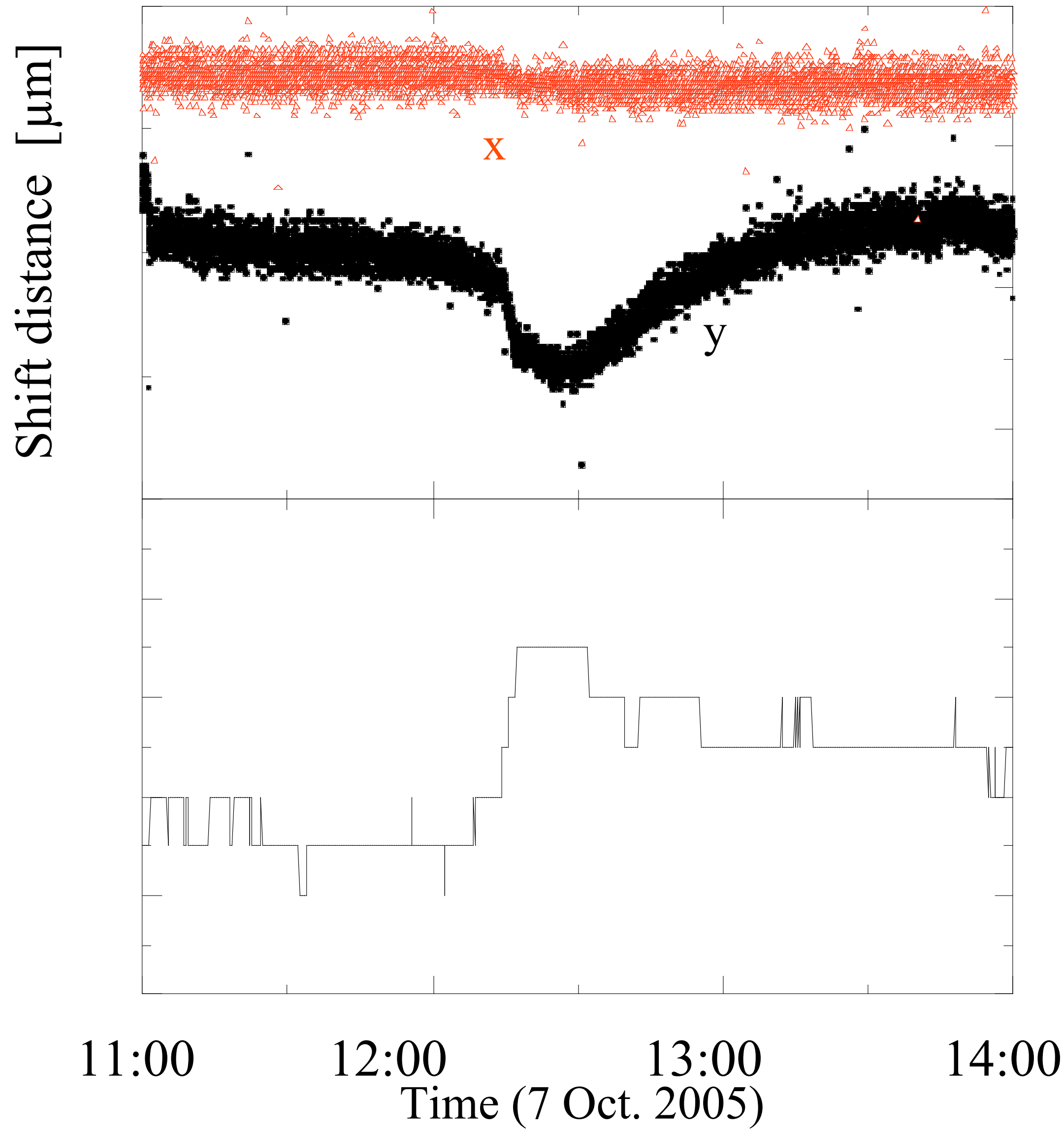


Alignment for thermal
Fluctuation (±1°C)



Alignment for
fast error

Experimental results of the Position Stability of Oscillator with Synchronization locking(714MHz)

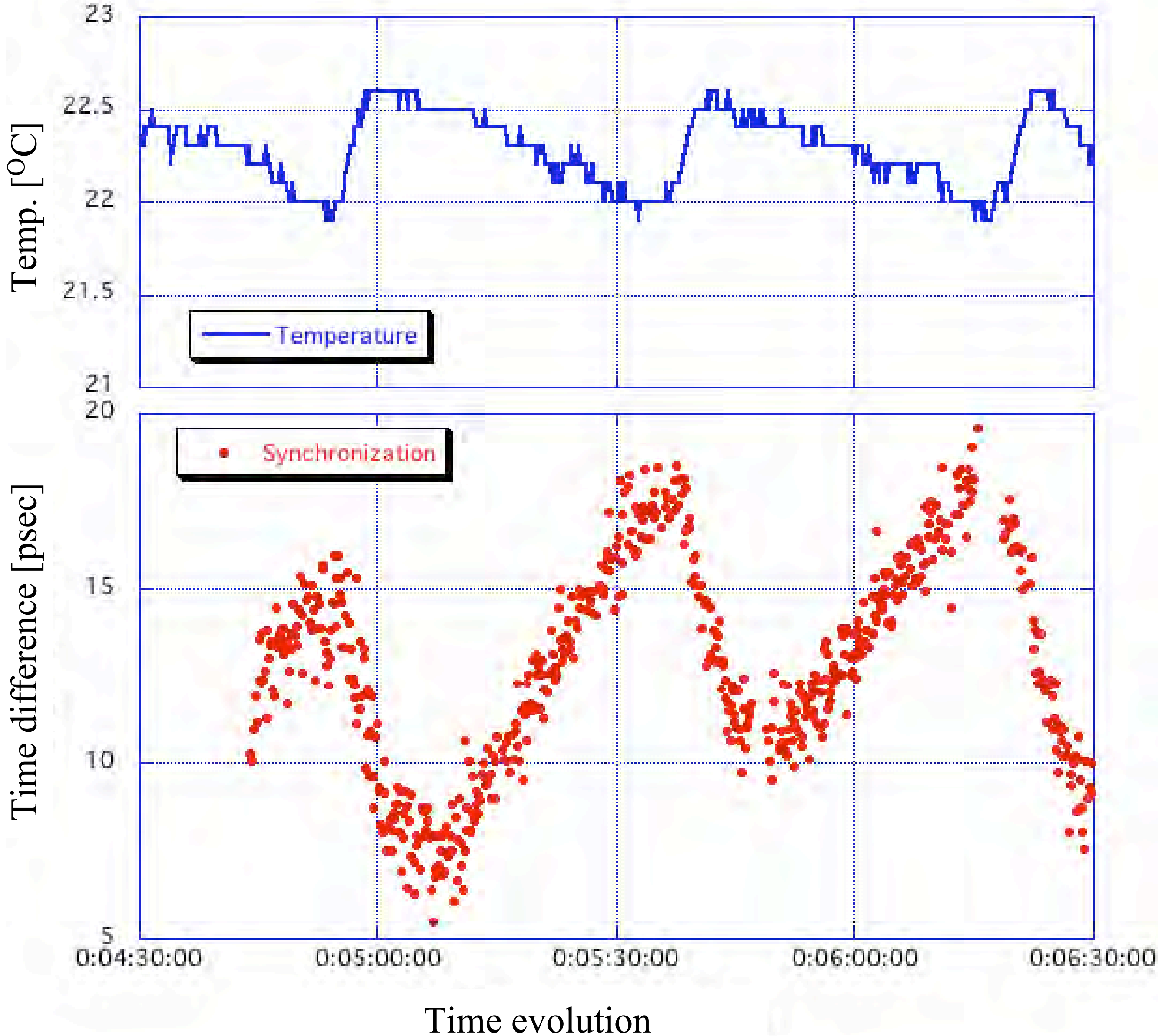


We measured the position stability with synchronization locking at the position of **1m** from oscillator, using quadcell photoreceivers.

When the room temperature shifts rapidly, position y shifts 5 μm.

The fluctuation of the room temperature cause the position of the position stability.

The drift of the Laser-room temperature has much effort to Synchronization between laser and electron beam



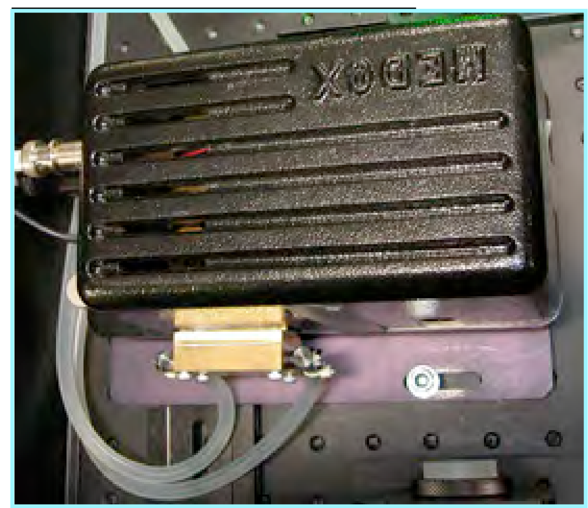
Operation for Long-term stability by water cooling

In laser room, there are a lot of local thermal source, especially pumping YAG laser and Pockels cell make bad influence to Oscillator and regenerative timing.

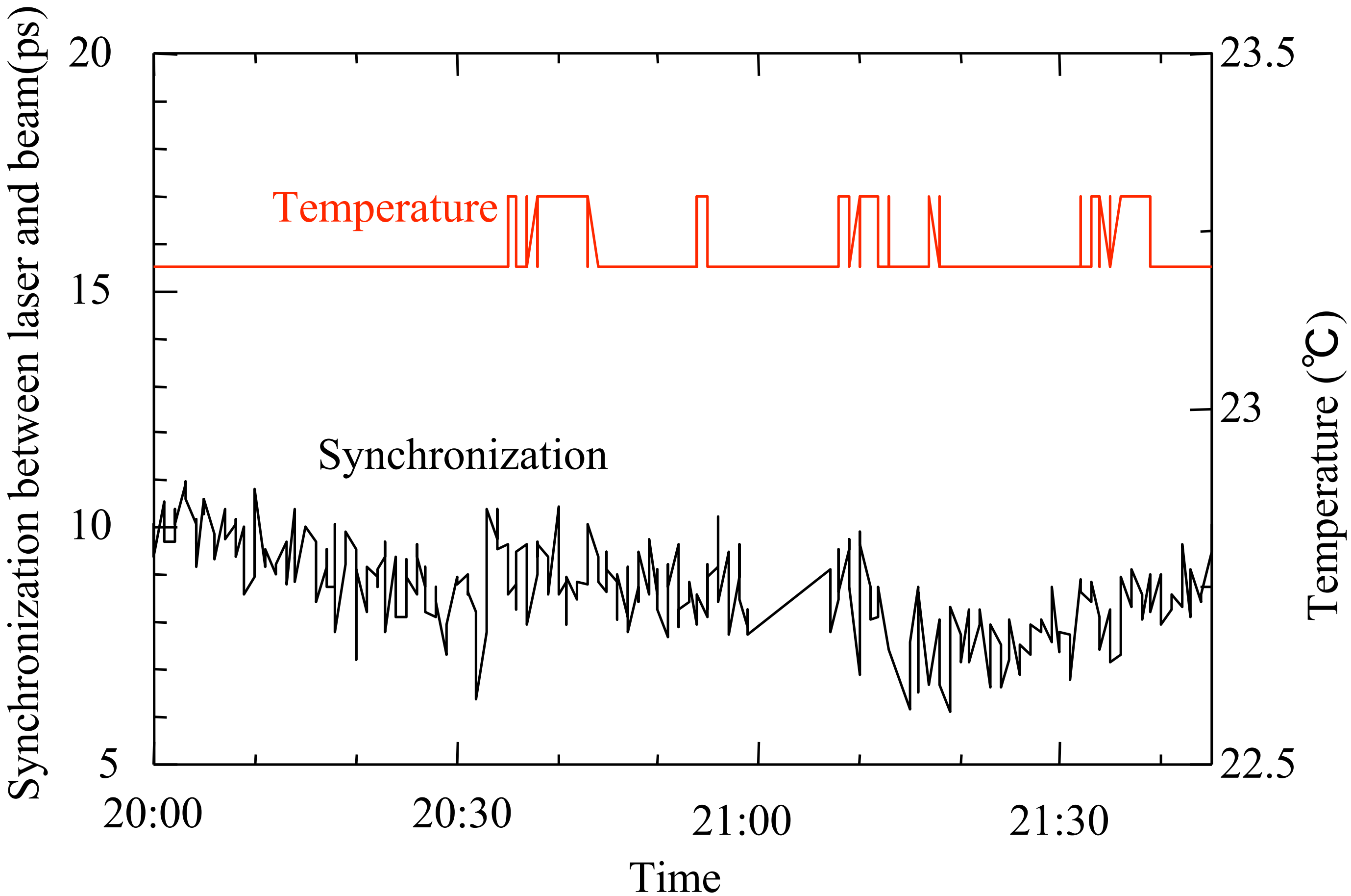
In order to suppress local thermal modification, we do water cooling to laser case and Pockels cell by Spring-8 method.

Base plate:Water cooling :suppress distortions of case

Pockels cell Suppress local thermal modification:

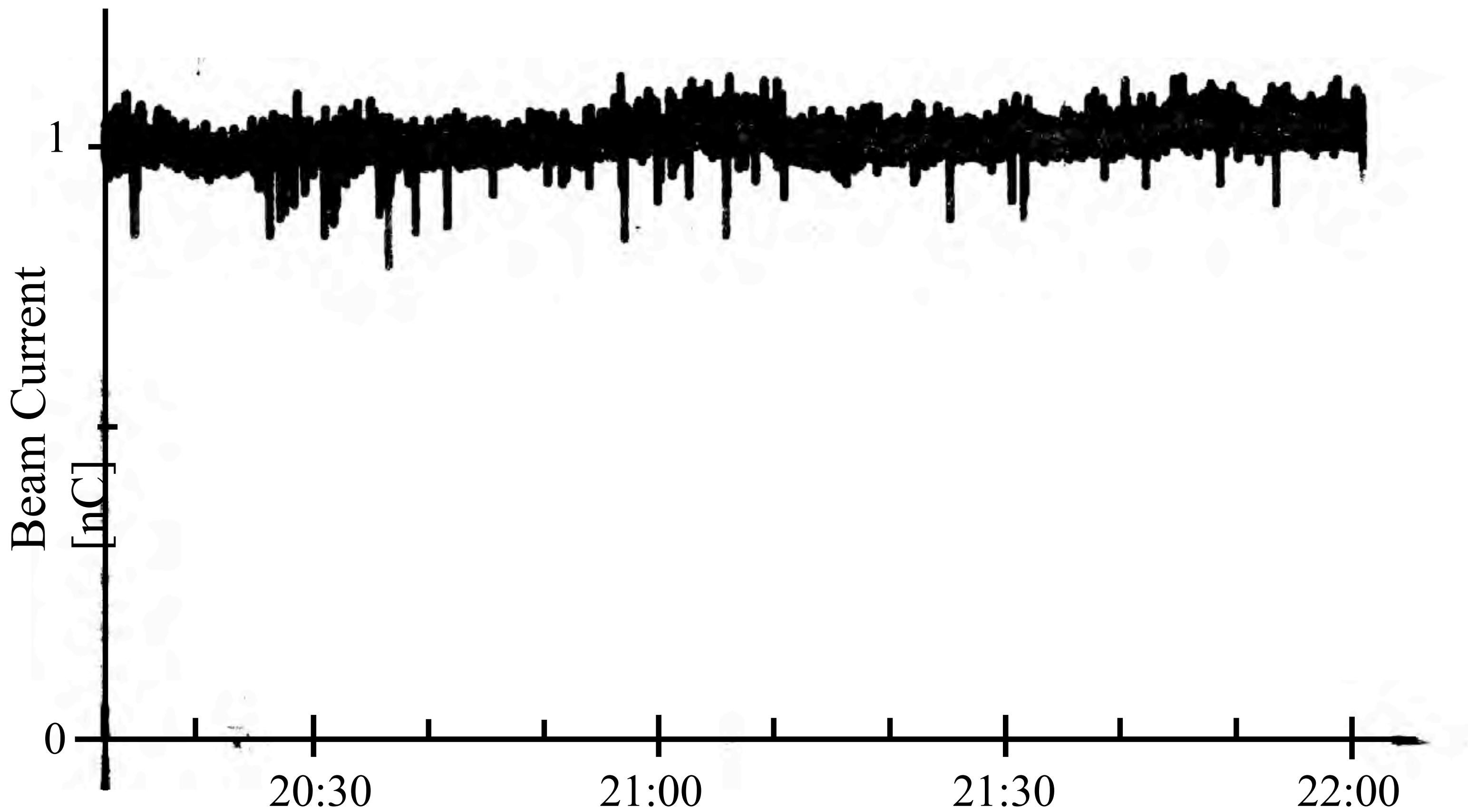


Correlation between Laser-room temperature and Synchronization



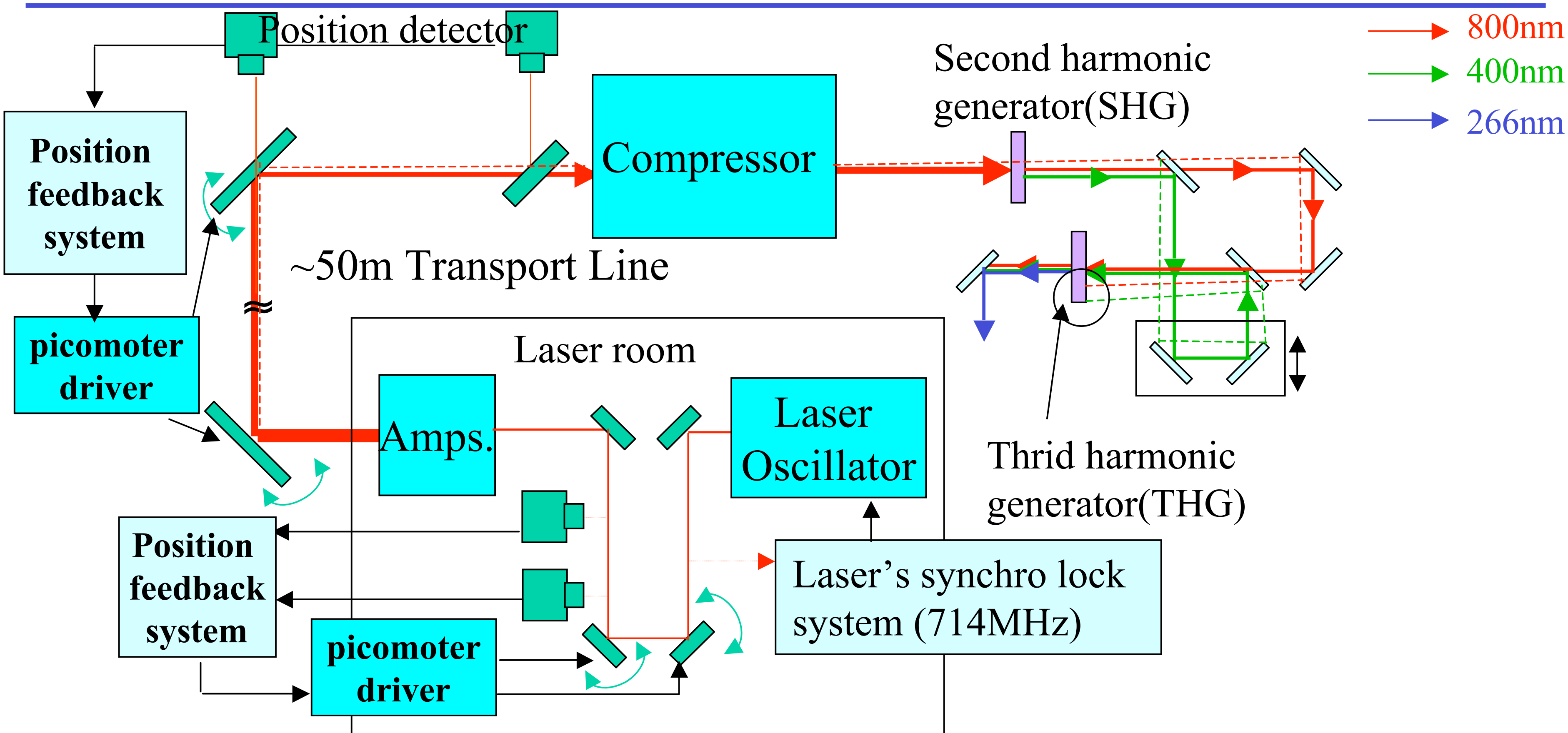
From 20:00 to 21:30, we could keep the laser room temperature shift within 0.1 ℃, so that we could see no-drift and timing jitter is estimated as 600 fs (rms).

Beam current stability



The electron beam stability is 4%(rms) during 1 hour (20:30-21:30).

Feedback system for position stability



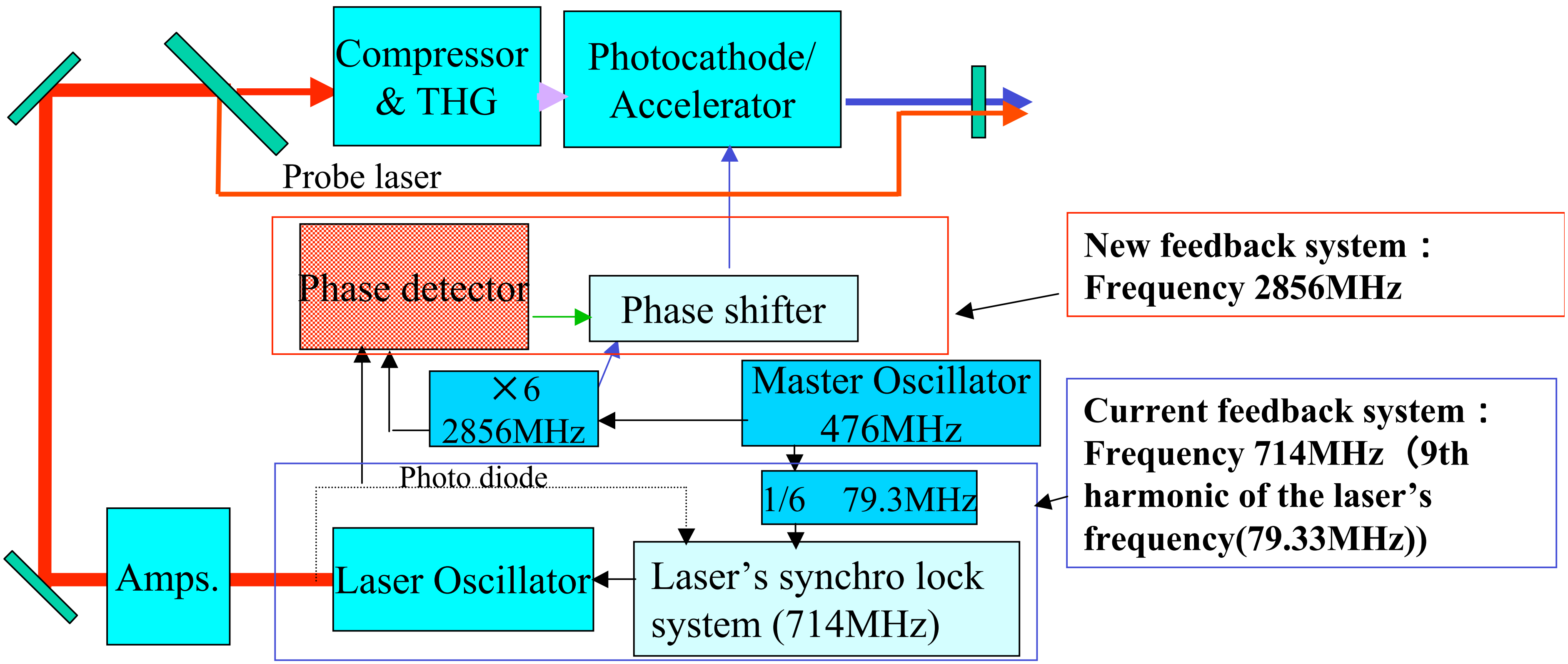
・Distance between laser room and compressor+THG is about 50m. Therefore it is easy to misalign (Transport line doesn't keep the temperature control.)

・If optical line of the laser is misaligned, compression at the compressor or third harmonic generation become worse.

→ Decreasing of the electron beam intensity.

In order to stabilize the beam intensity, we have to stabilize the laser position by active feedback.

Phase Feedback system



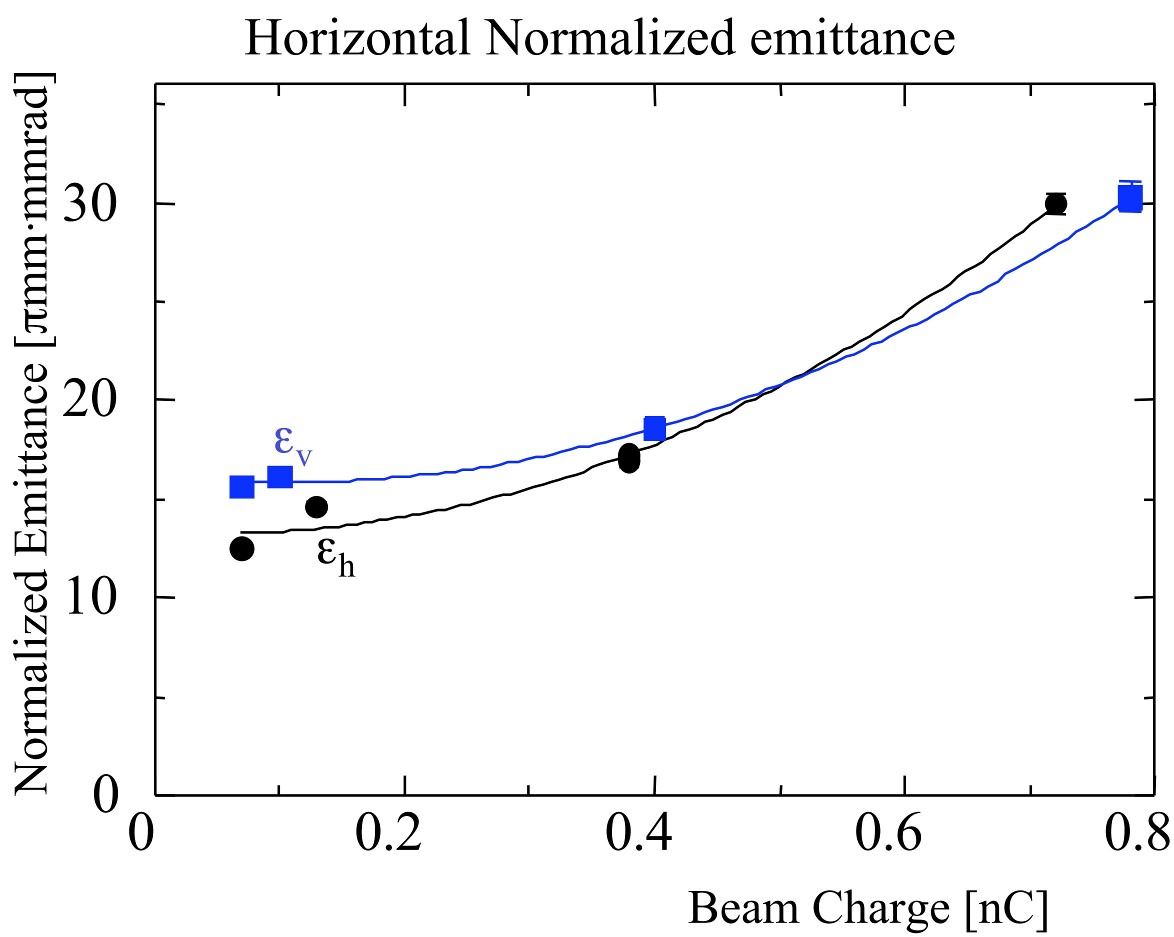
The phase between accelerator and laser shifts slightly during long term operation

Guess：Laser's synchro lock system shifts the phase of the laser??
（The frequency of laser synchro is _(4th sub-harmonic) . It's not enough to synchronized??）

We are installing phase shifter, to fix the accelerator phase to laser's. (2856MHz feedback)

Emittance

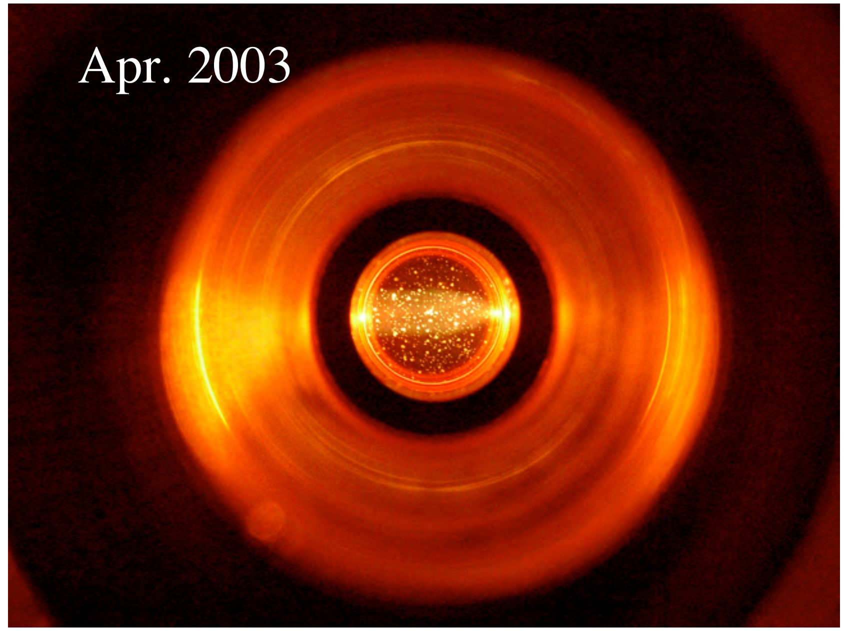
- Measured by double slit scan (slit distance 400 μm)



At 70pC,
ε_h=12πmm·mmrad
ε_v=15πmm·mmrad

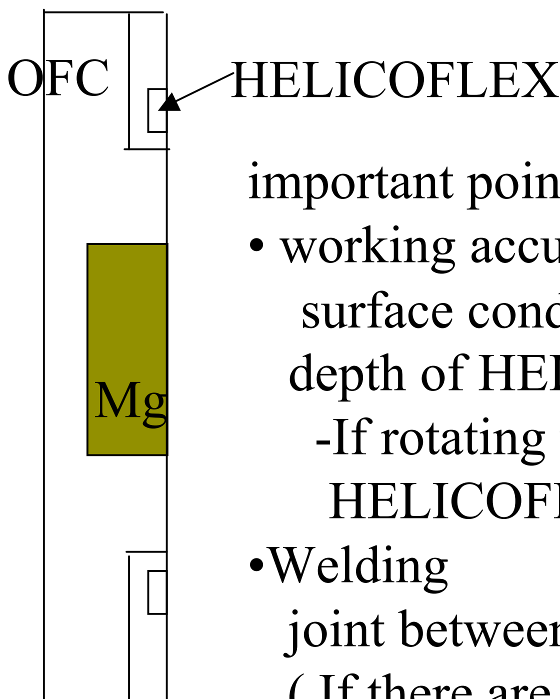
Damage of the cathode surface??
Optics un-matching??

Mg Cathode Surface



・Many craters by RF discharge or laser irradiation

Necessity of re-build

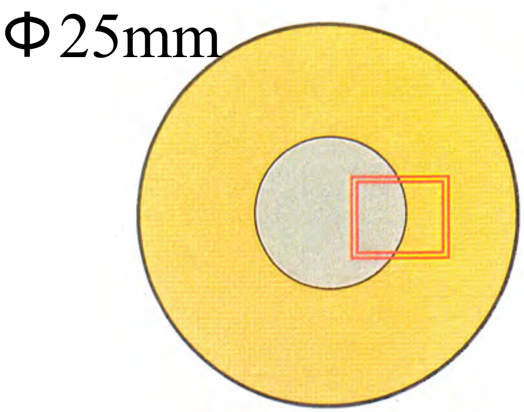


important points are following:

• working accuracy (<50 μm)
  surface condition of Mg and Cu
  depth of HELICOFLEX groove
    -If rotating torque is weak, discharges may occurs around HELICOFLEX.

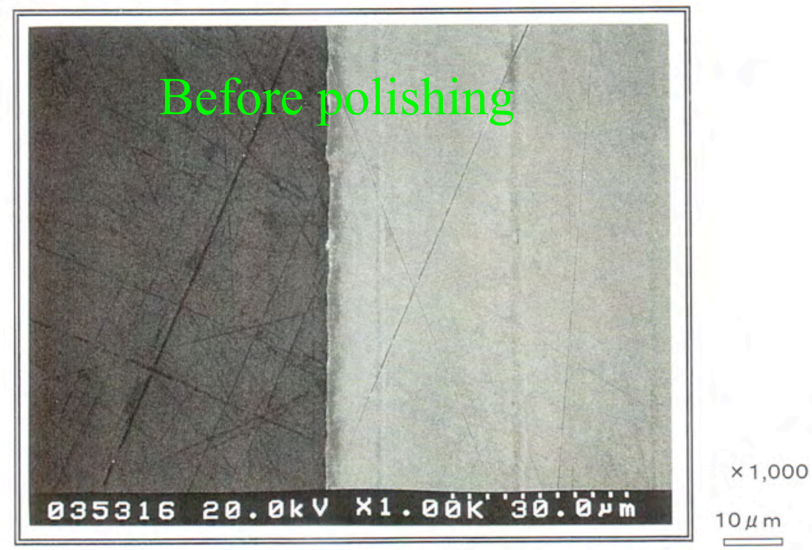
•Welding
  joint between Cu and Mg (polishing is also important)
  (If there are gutters, discharges will happen)

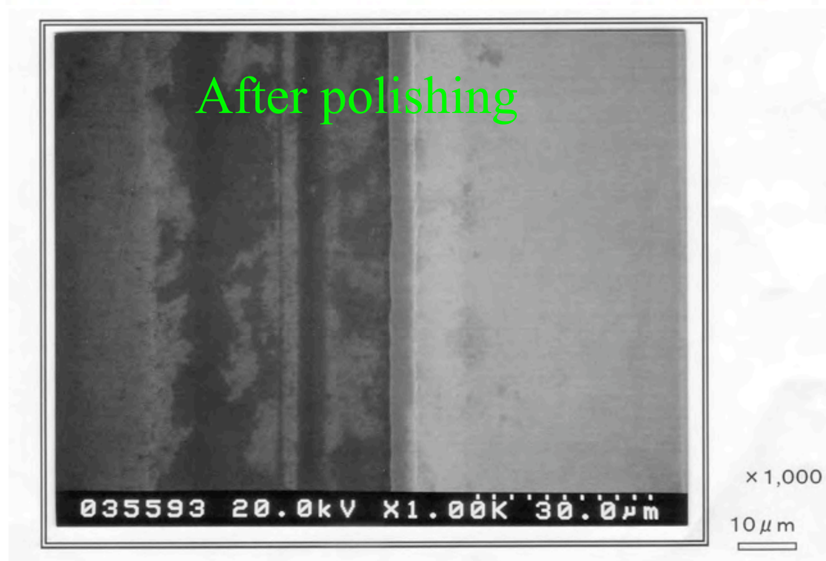
SEM image of the prototype Mg-cathode



position

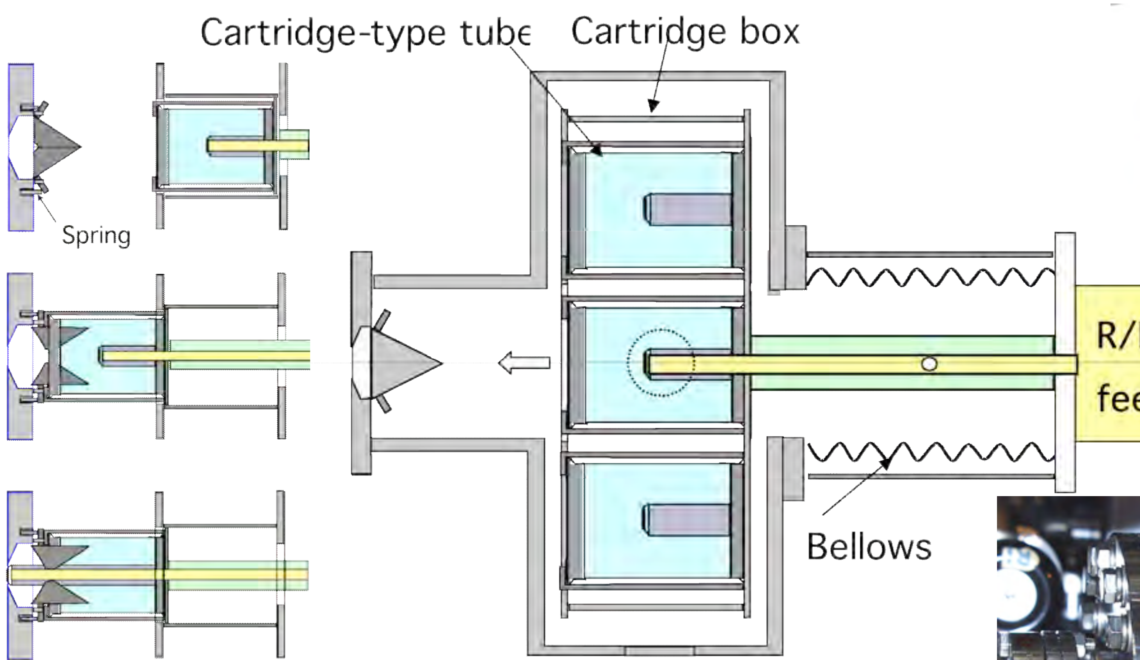
There are no channel between Cu and Mg



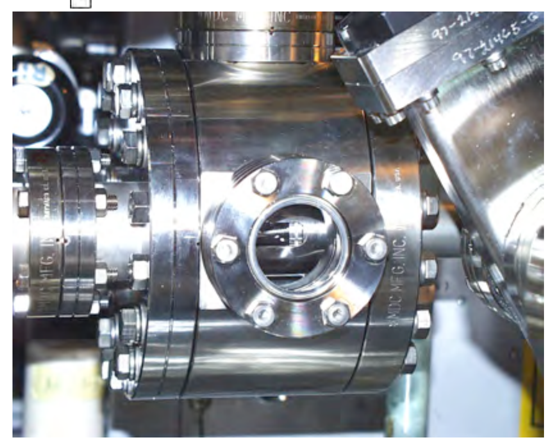


Future Plan: Cartridge type Cathode

Compact and re-changeable cathode.
Cathode can be created outside.



Reflection-type
Cs_2Te tube



Spring-8/HPK/U-Tokyo

Now we are developing to install….

Summary

・We can reduce the fluctuation of room temperature within 0.1 degrees
We can observe a good synchronization of 600 fs between the pumping electron beam and the probe laser in an hour.

It has the potential to do the experience of the pulse radiolysis experiment in an hour.

In order to synchronize in long period as one-day, we are developing to new feedback system of phase matching and point stabilizing.

Introduction of Multibunch beam in KEK

- A multibunch photo-cathode RF gun system has been developed as an electron source for the production of quasi-monochromatic X-rays based on inverse Compton scattering.

RF Gun Test Bench

- We constructed a RF gun test bench at an assembly hall in KEK to conduct the generation test of the high intense beam with low emittance and low energy spread.

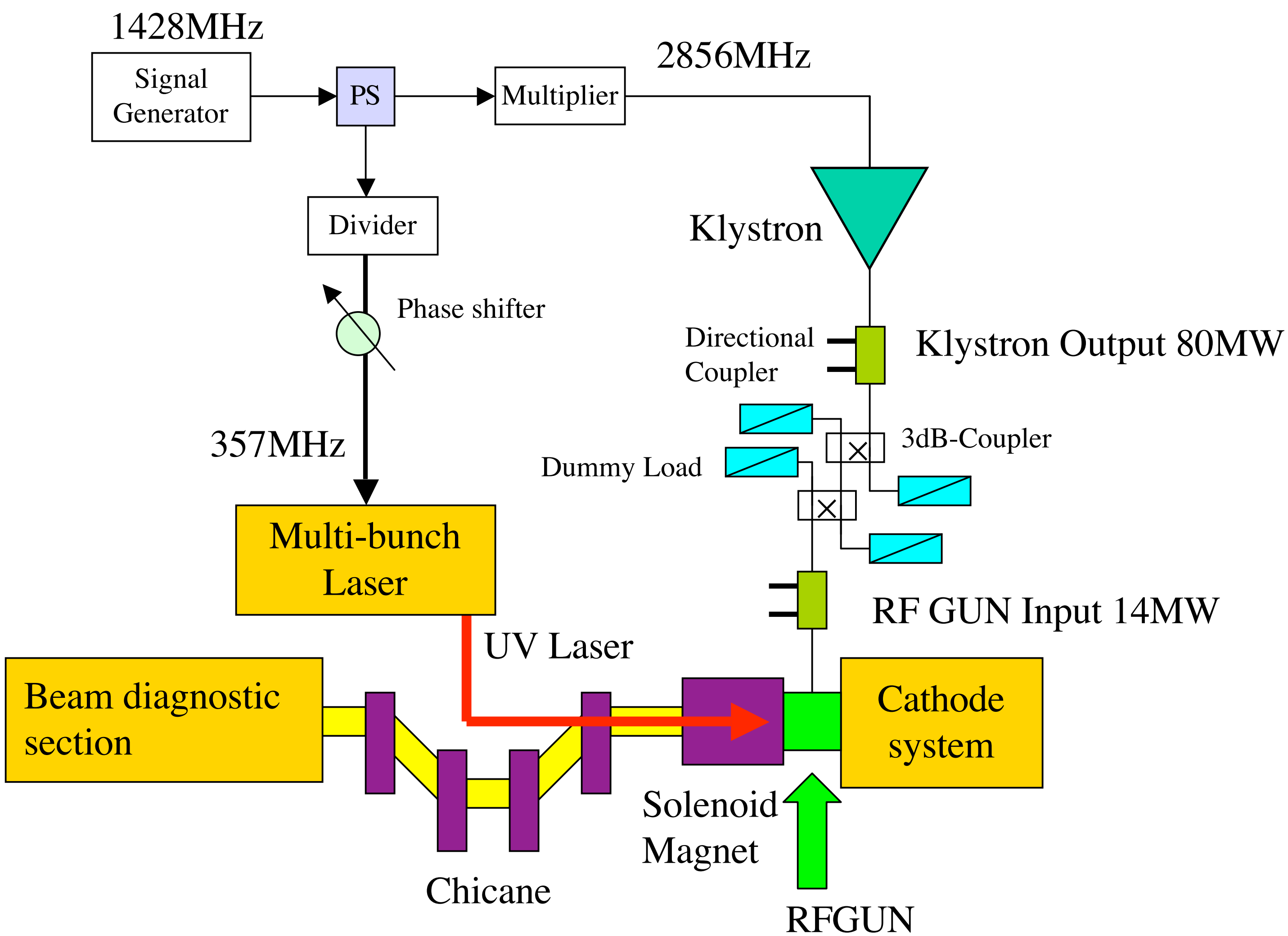
Multhibunch Beam （5nC/bunch、100bunches/pulse、 5 π mr

- We started the test run on September 8, 2004, and have observed a beam with 5 MeV for 280nC/100bunches.

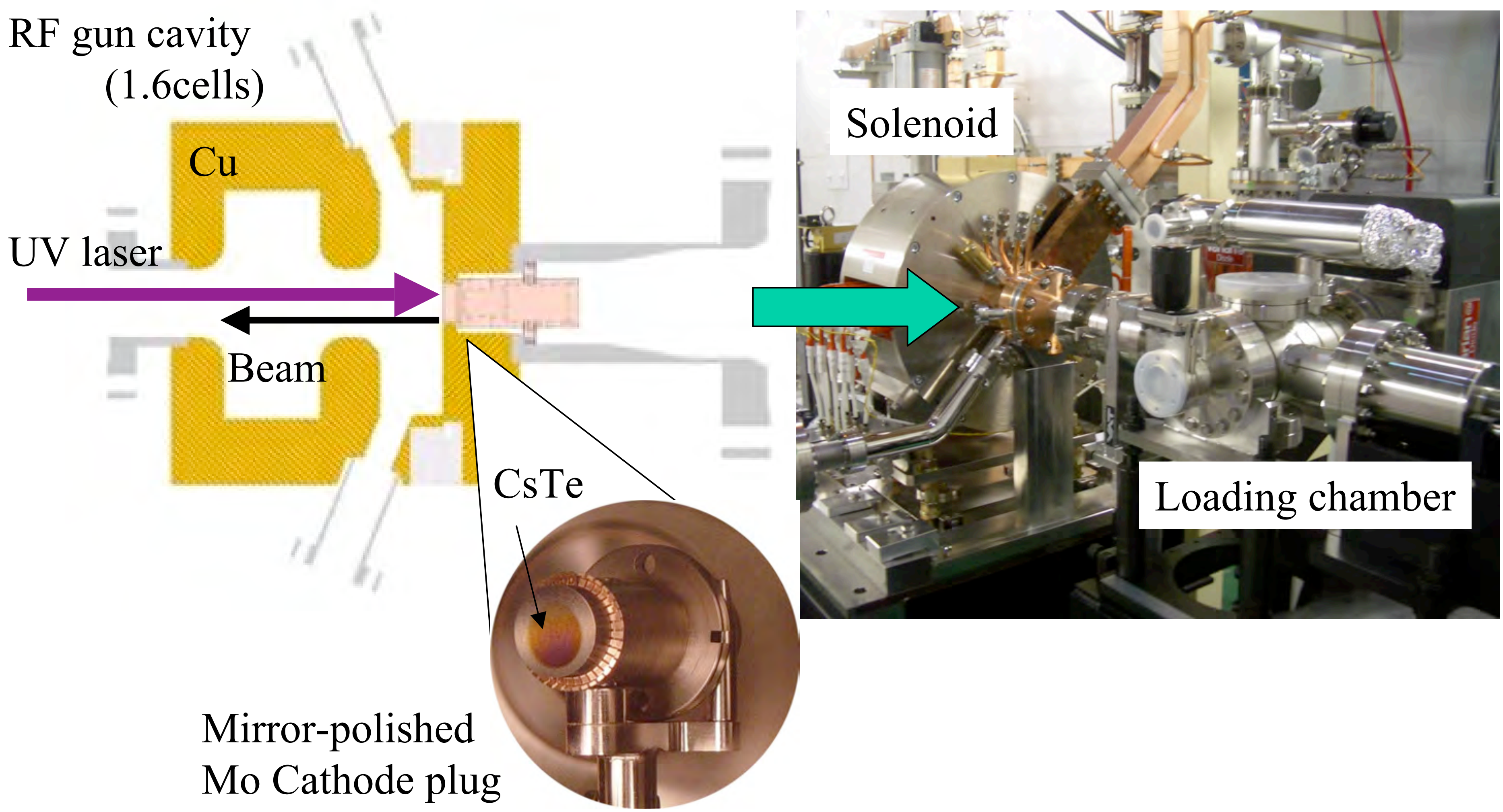
Components of RF Gun Test Bench of KEK-ATF

- *Combination of BNL-cavity and CsTe cathode*
  - 1.6 cells standing wave cavity with laser photo-cathode.
  - CsTe had QE (～1%) at 266nm.
- *Cathode system*
  - A load lock system allows to change and transport the CsTe cathode plug without breaking a high vacuum.
- *Laser system*
  - A laser system consists of a 357MHz mode-locked Nd:YVO4 oscillator with output power 7W at 1064nm and two flash lamp pumped amplifiers with double pass system.
- *Chicane*
  - Illuminating the cathode at a head-on incidence.
- *Beam Diagnostic Section*
  - Study for the peculiarity of the multibuch beam.

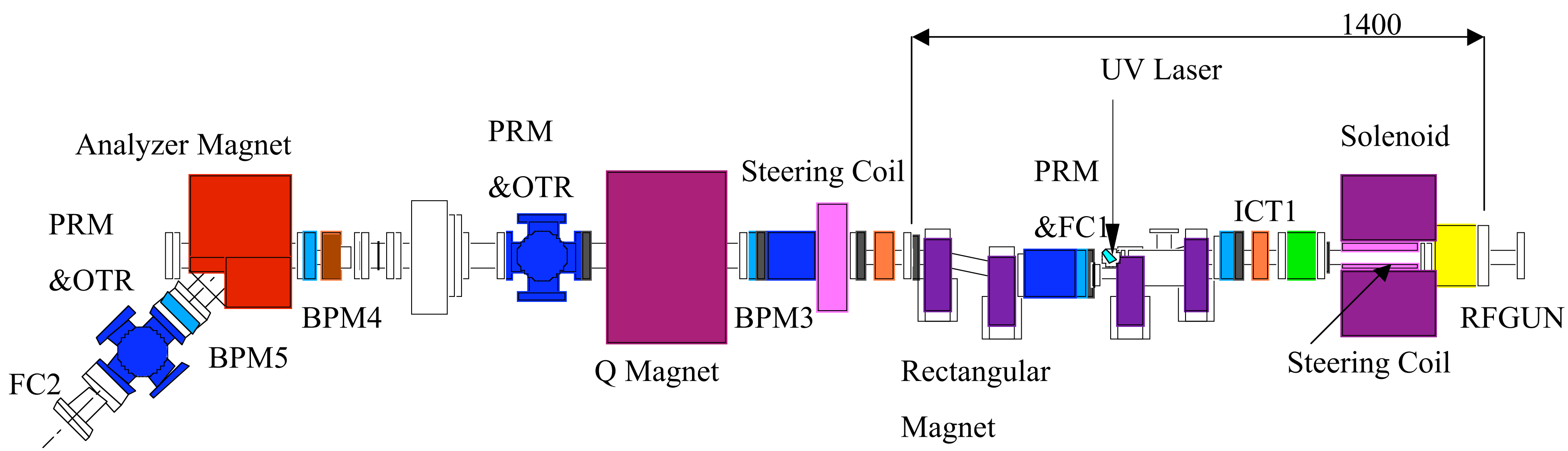
Schematic of the RFGUN Test Bench of KEK-ATF



RF-gun Cavity & Cathode Plug of KEK-ATF



Beam Diagnostic Section of KEK-ATF



ICT: Integrate Current Transformer

WC: Wall Current Monitor

BPM: Beam Position Monitor

PRM: Profile Monitor

GV: Gate Valve

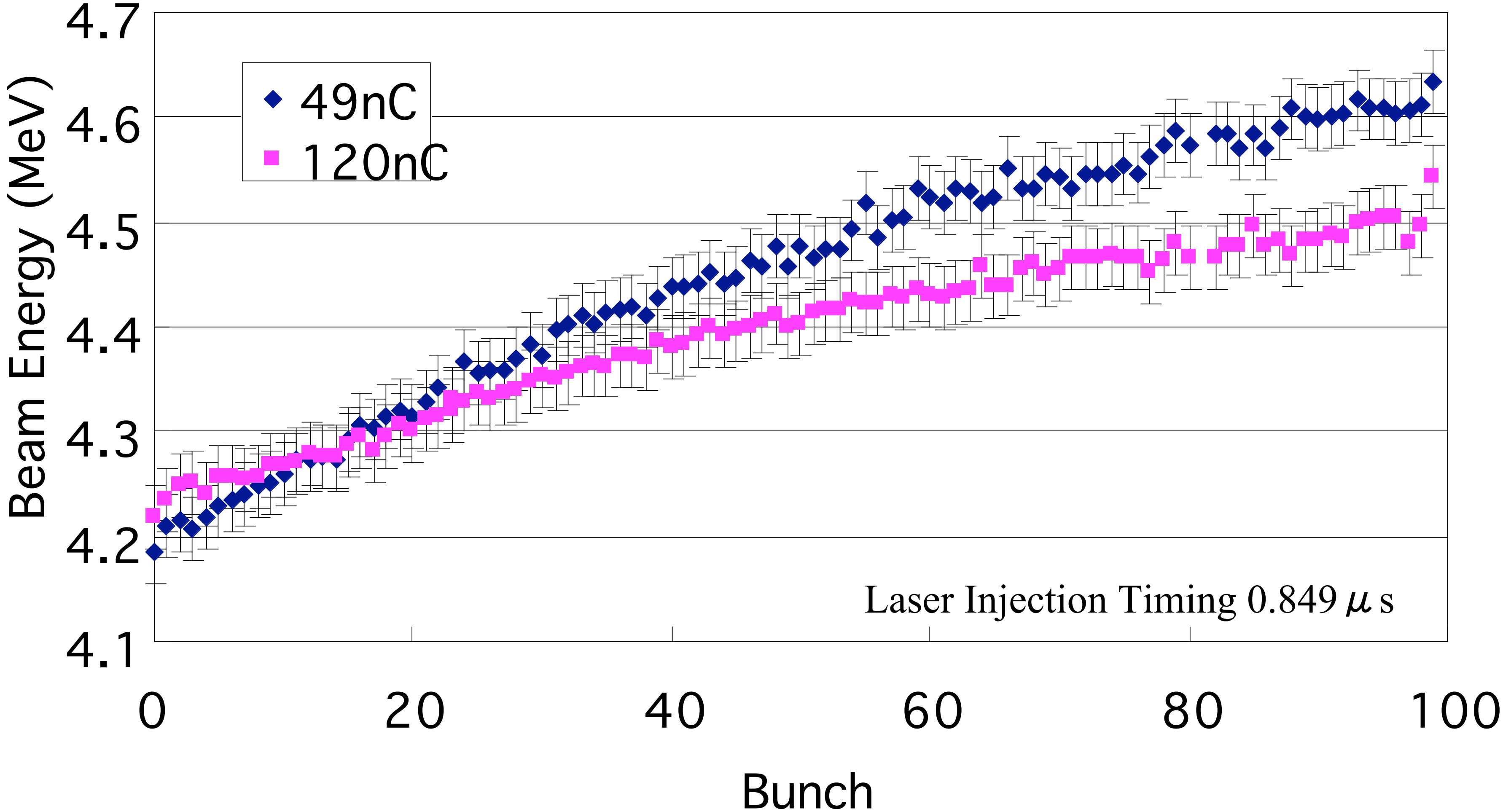
FC: Faraday Cup

Bunch-by-bunch Beam Energy of KEK test bench

The beam energy of each bunch was measured by using the analyzer magnet and the beam position monitor (BPM5).

Charge ??C/100bunches)	RF pulse width ??sec?	Laser injection timing ??sec?	Beam energy of first bunch ?MeV)	Beam energy of 99th bunch ?MeV)	GUN input power?MW)
230±10	1.8	0.849	4.21±0.04	4.25±0.04	12.2±0.1
120±5	1.8	0.849	4.22±0.04	4.48±0.04	12.1±0.1
49±2	1.8	0.849	4.19±0.04	4.61±0.04	12.1±0.1
49±2	1.8	1.409	5.04±0.04	5.09±0.04	12.1±0.1
280±10	1.8	1.409	4.99±0.04	4.50±0.04	12.1±0.1

Bunch-by-bunch Beam Energy of KEK test bench



Requirements

Pulse radiolysis in a time range of sub-picosecond

I Ultra-short bunch and laser

- Pump-beam: Utilization of a chicane-type magnetic compressor
- Probe-laser: Femtosecond laser

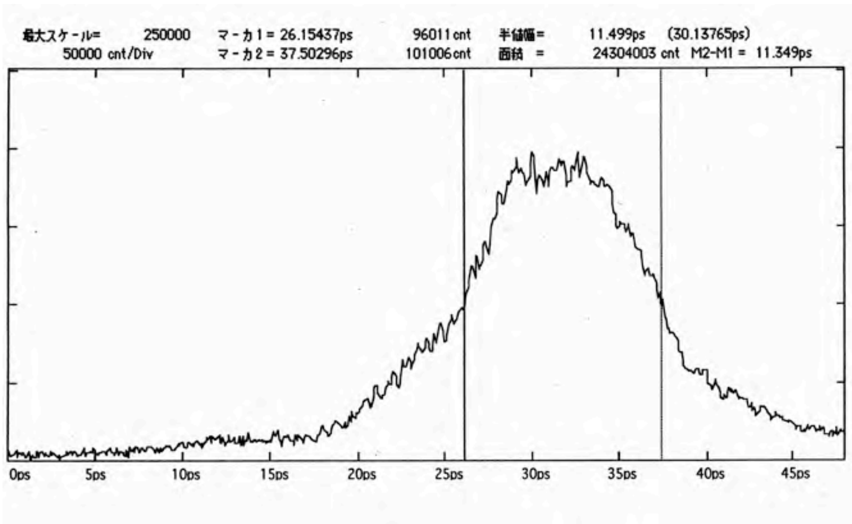
II Stable synchronization

- Jitter: Synchronization lock frequency
- ***Drift:*** Laser transport line & ***Laser room temperature***

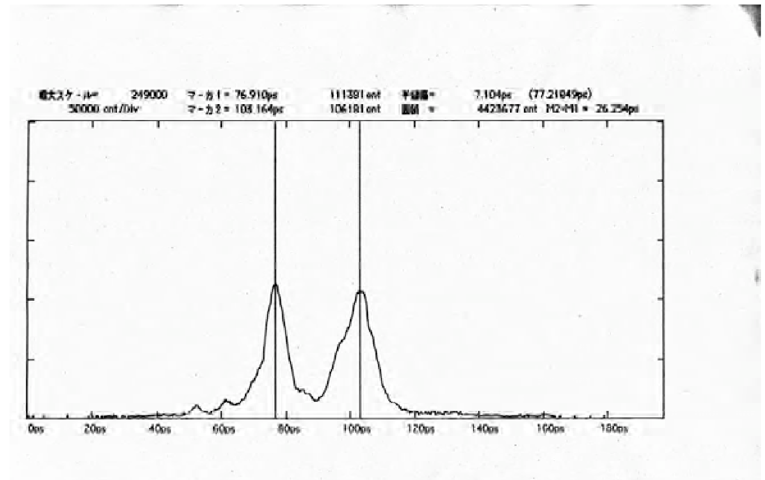
III Intense electron bunch

- High QE: Mg cathode & Laser cleaning (future plan)

Problem of DIGITEX circuit



Beam : ten shots summary

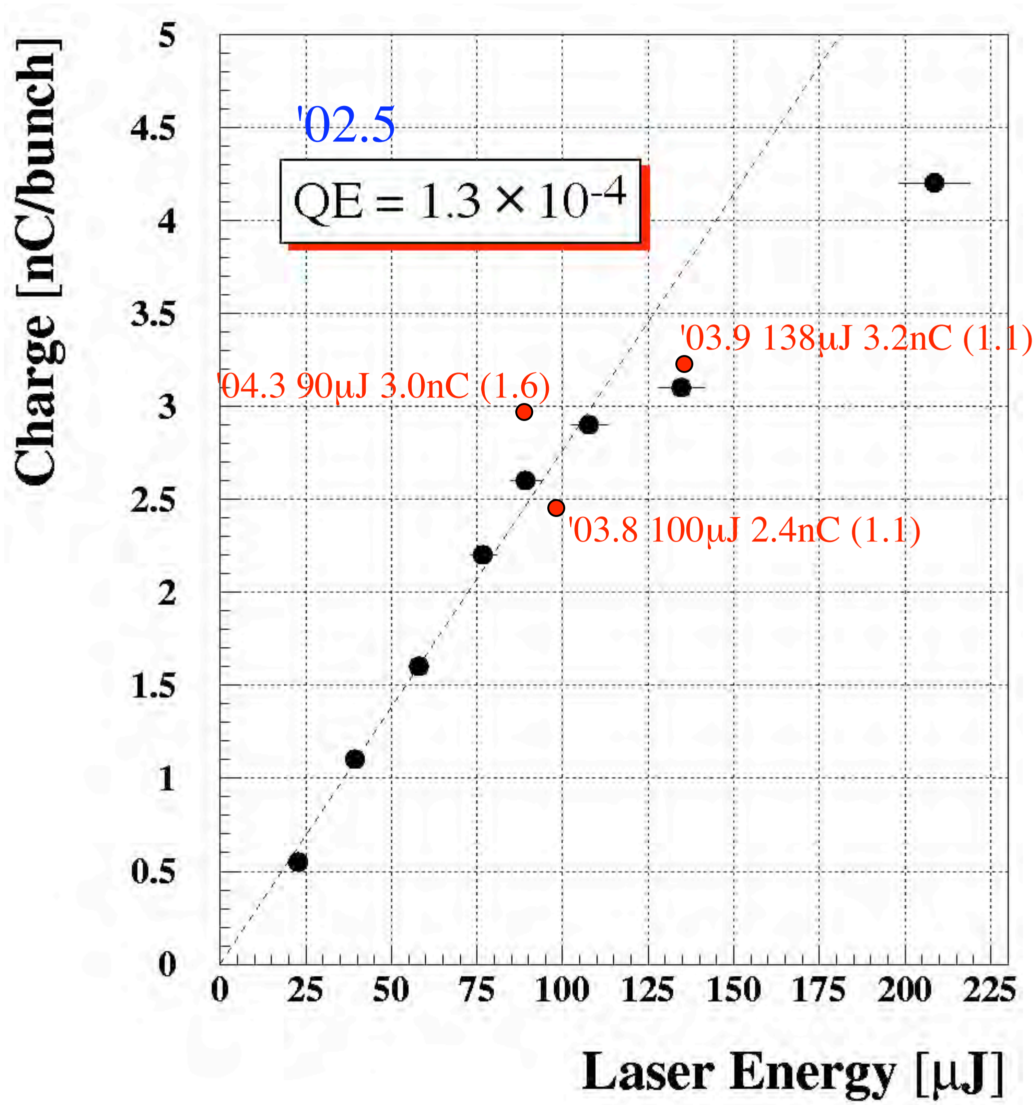


laser : ten shots

Jitter: FWHM11.35ps
Misfire(?): 26.25ps

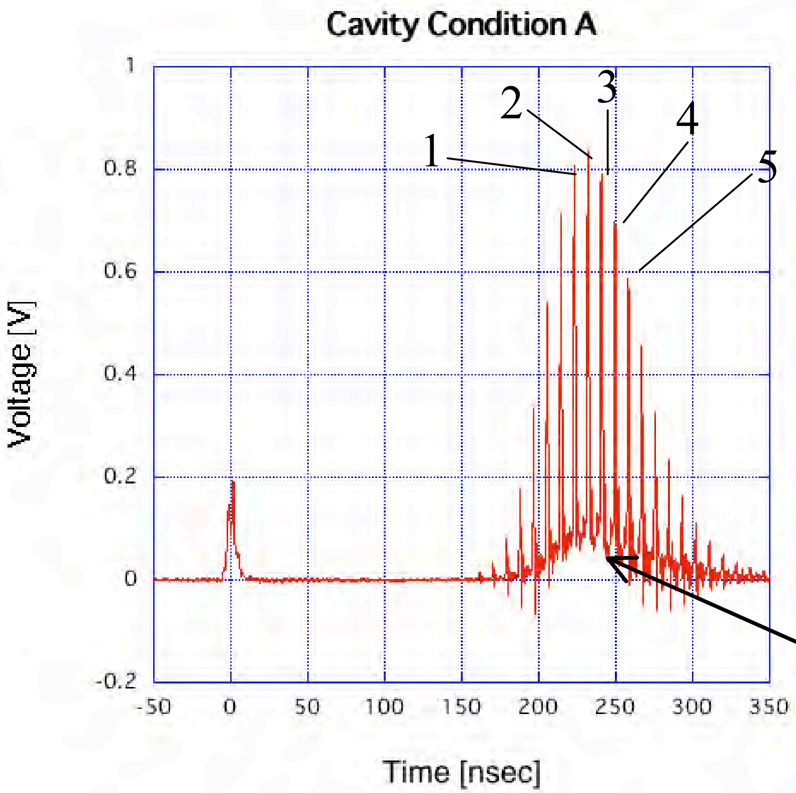
Relative synchronization is good, however absolute synchronization (ex. Between streak camera and beam) is not yet. To get better synchronization, we have to improve sub-harmonic generator (DIGITEX).

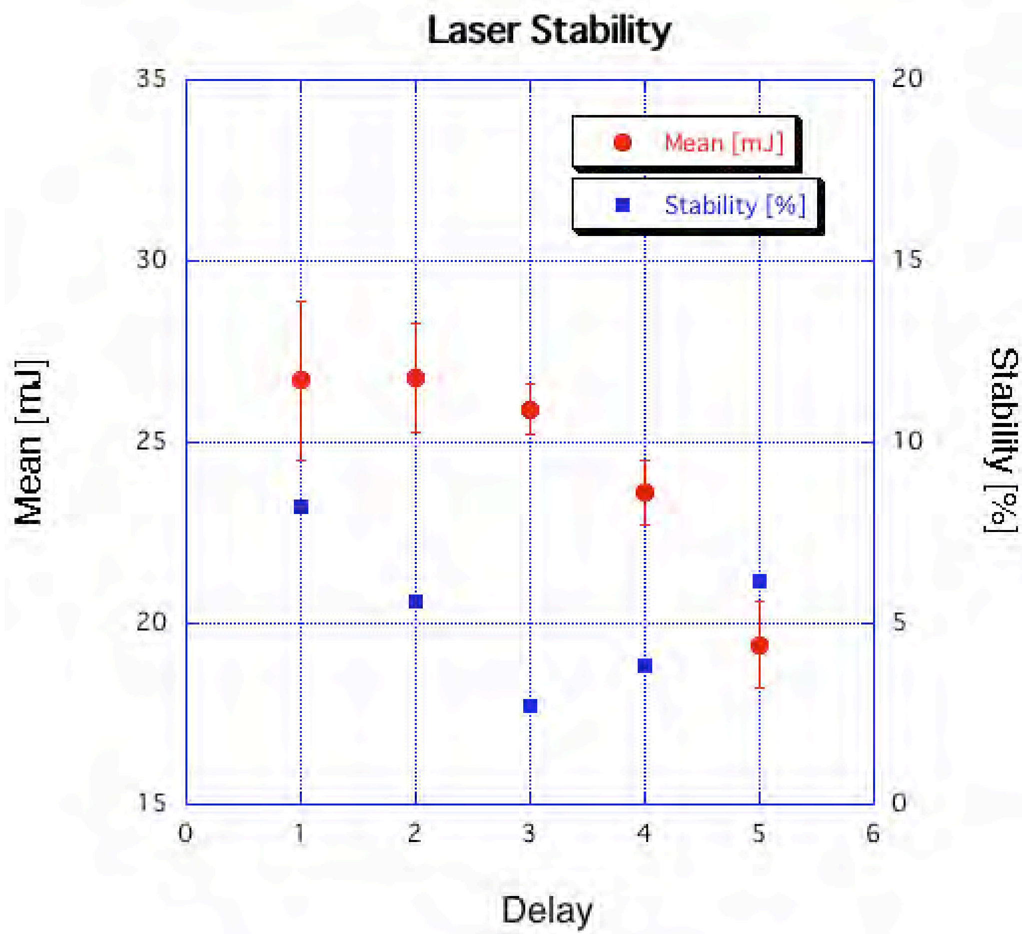
Quantum Efficiency



Stability of Regenerative Amp.

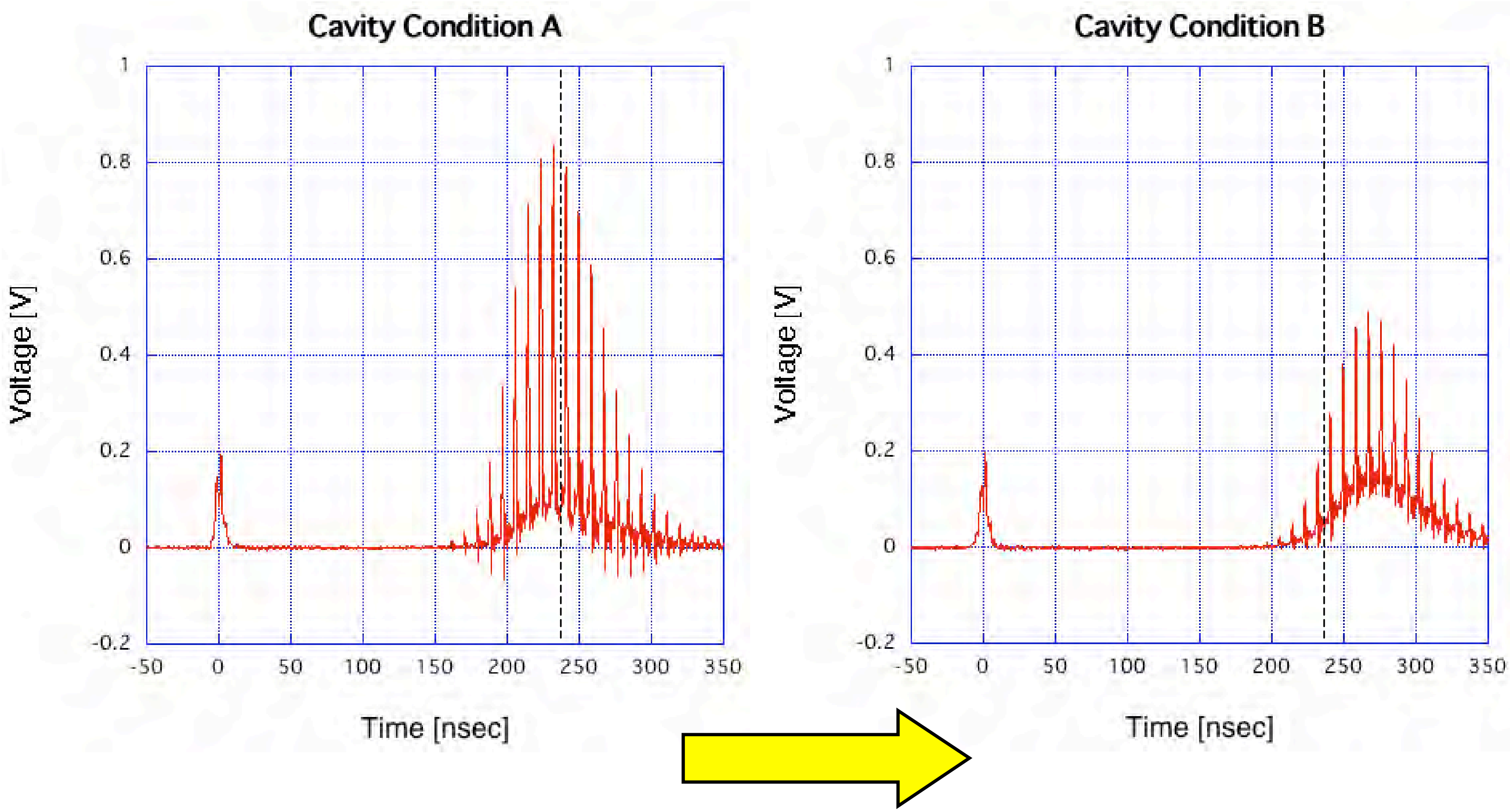
These results indicate the fluctuation of the fundamental laser.





Growth of the light in the cavity

Regenerative Amp. depending on Temperature



The timing of laser-growth in the cavity also depends on the laser-room temperature. This process causes the laser-power fluctuation.

Development for visible laser driven metal cathode

・Advantage:
long life (than semi-conductor or alkali cathode)
high resistive for high electric field, discharge laser ablation

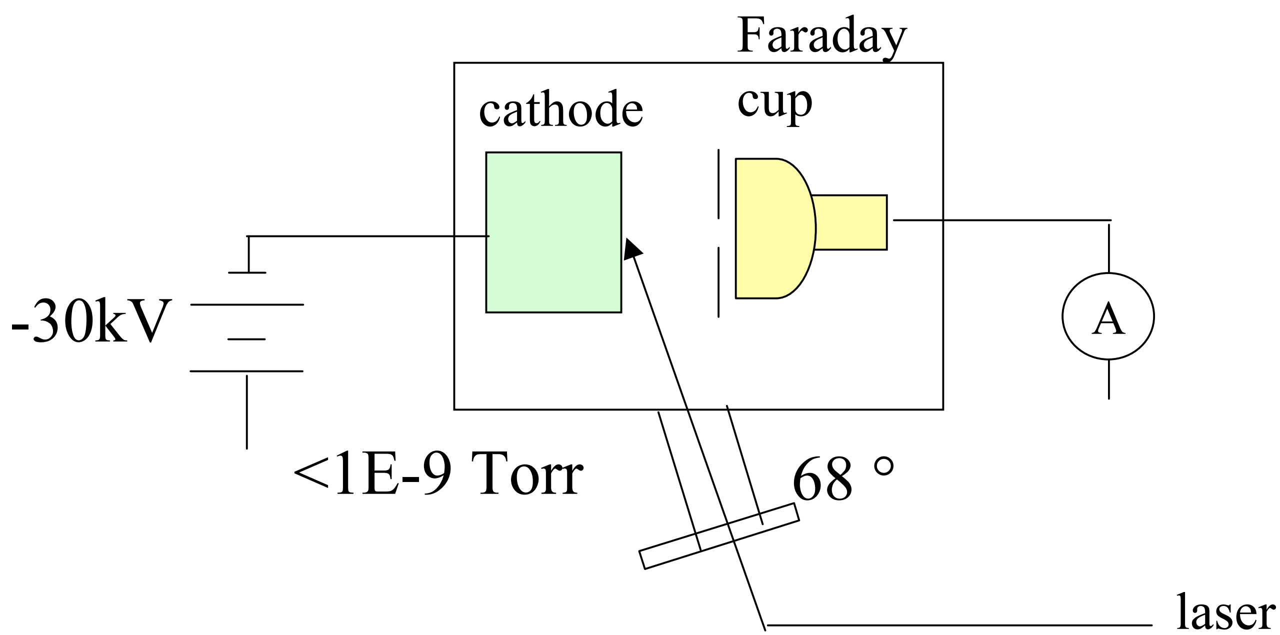
・Disadvantage
quite low QE

If we get the QE with 400nm as ~1E-5, same magnitude of cupper's with 266nm, the total charge increases…

・aiming wavelength　400nm（Ti:Sa 2nd harmonic）
350nm（Nd:YAG,Nd:YLF 3rd harmonic）

・Cathode material ：Pb-Cs
Mg-Cs, Ag-Cs (Ag -O-Cs)
W-Cs（Cs ion dispenser ）　（JLab）

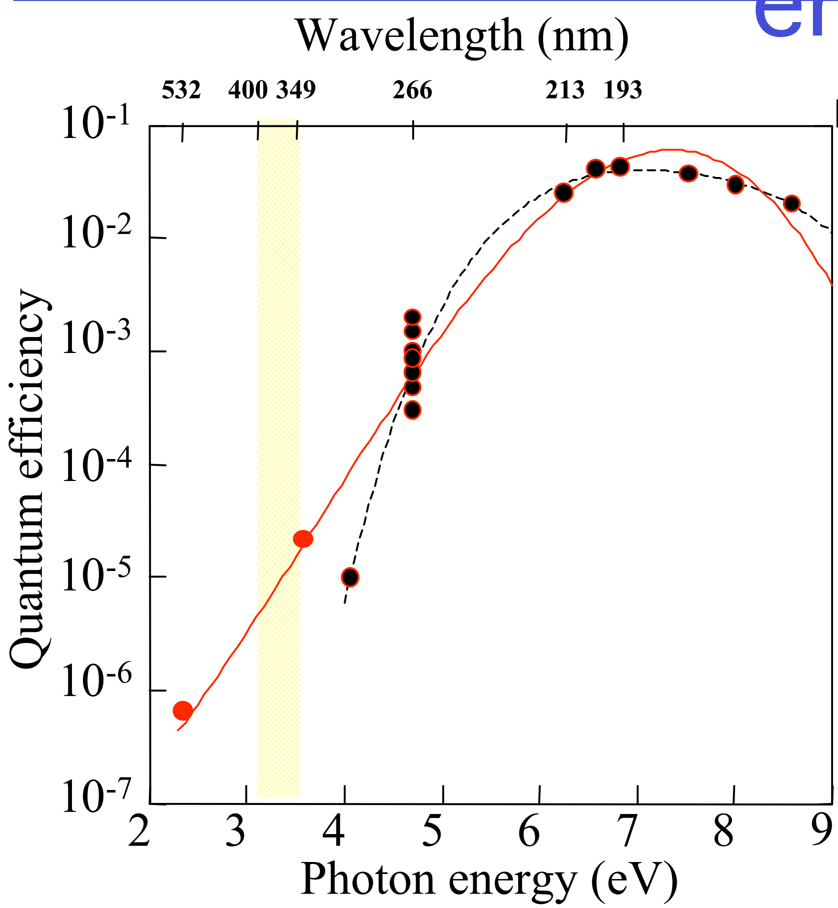
Measuring QE of the each cathode



30kV during 3mm（1MV/m)
Laser wavelength: 266nm（Ti:Sa 3rd)
400nm（Ti:S
355nm(Nd:YAG 3rd)

continuum light from OPA(in future)

QE of Mg cathode vs photon energy



4.0~8.5eV : Triveni Srinivasan-Rao et al. (BNL)

2.3eV(532nm) Beijing U. (NIMA445(2000)394)

3.6eV(349nm) : SHI (JJAP42(2003)1470)

■Schottky effect ~0.4eV(25MV/m)

QE~10^{-5} !?

•Q[nC]~QE*λ[nm]/124*E[uJ]

Charge Q 400/266~1.5time higher

■Mg's damage threshold ：500μJ/mm^2

working point（<10μJ/mm^2）

Enable to increase

QE_effective

QE_eff~10^{-4} !?

■Cs implantation:10 times higher

(*cf* NIMA445(2000)394)